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The Hollow Penny

Student Laboratory Kit

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Introduction:

Pennies are made of copper, aren't they? The outside is certainly made of copper, but that's not the whole story. In this lab, the composition of two pennies from different years will be investigated.

Background:

Oxidation–reduction, or *redox,* reactions are reactions in which electrons are transferred from one element to another. A common type of redox reaction is a single replacement reaction. *Single replacement reactions* involve the replacement of one element in a compound with another element. The general form for single replacement reactions is shown in equation 1.

$$A + BC \longrightarrow B + AC \qquad (1)$$

Metals are commonly involved in single replacement reactions. Some metals can replace other metals in their compounds, while some metals cannot. In equation 1, if "A" and "B" are metals, "A" replaces "B" in its compound "BC". The reaction is not reversible, so "B" cannot replace "A" in the compound "AC". The ability to replace another metal determines a metal's reactivity—the better the ability to replace another metal, the more reactive a metal is. The activity series of metals is a scheme that places the metals in order of reactivity (See Table 1). The metals at the top are the most reactive and can therefore replace most other metals. Reactivity decreases as you move down the list, with those at the bottom of the list capable of replacing only a few other metals. A metal can replace another metal if it appears above that metal in the activity series. In equation 1, "A" must be the more reactive metal (higher up on the activity series and capable of replacing "B"), while "B" is the less active metal (lower on the activity series and not capable of replacing "A").

Increasing Activity ↑

Name of Metal
Lithium
Potassium
Calcium
Sodium
Magnesium
Aluminum
Zinc
Iron
Lead
(Hydrogen)
Copper
Mercury
Silver
Gold

Table 1. The Activity Series of Metals. *Note*: Hydrogen is listed in the activity series even though it is not actually a metal. For the purposes of the activity series, it is considered to behave as a metal.

Looking at a specific example, if the two metals are aluminum, Al, and copper, Cu, then in equation 1 "A" must be aluminum and "B" must be copper since aluminum appears higher up on the activity series than copper and is therefore a more active metal than copper. An example of a reaction involving these two metals is the reaction between aluminum metal and cupric chloride solution (see equation 2).

$$2Al(s) + 3CuCl_2(aq) \longrightarrow 3Cu(s) + 2AlCl_3(aq) \qquad (2)$$

In this reaction, aluminum is said to *replace* copper since the cupric chloride compound becomes aluminum chloride. In redox terms, the cupric ion has been reduced to copper metal, while aluminum metal has been oxidized to the aluminum ion. Because copper appears below aluminum on the activity series, it is less reactive than aluminum and cannot replace aluminum in a compound. As a result, the reverse of equation 2 does not occur spontaneously (see equation 3).

$$Cu(s) + AlCl_3(aq) \longrightarrow NR \qquad (3)$$

Chemical Concepts:

- Activity Series of Metals
- Redox reactions
- Single-replacement reactions

Materials:

Balance
Beaker, 150-mL
Beaker, 250-mL
Graduated cylinder, 50-mL
Hydrochloric acid solution, 6 M, HCl, 40 mL
Paper towels
Post-1982 penny
Pre-1982 penny
Tongs
Triangular file
Water, 125 mL

Safety Precautions:

Hydrochloric acid solution is corrosive to skin and eyes and is moderately toxic by ingestion and inhalation. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron.

Procedure:

Day 1:

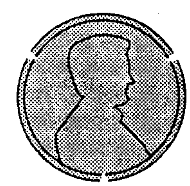

Figure 1.

1. Using a triangular file, file three notches in a pre-1982 and a post-1982 penny. See Figure 1.
2. Weigh the notched pre-1982 penny on a balance. Record its weight in the Data Table.
3. Weigh the notched post-1982 penny on a balance. Record its weight in the Data Table.
4. *Caution: 6 M hydrochloric acid solution is corrosive to skin and eyes. Avoid all contact with skin and eyes.* Pour about 40 mL of 6 M hydrochloric acid solution into a 150-mL beaker.
5. Using tongs, place both pennies in the beaker of hydrochloric acid solution so that they are both completely submerged.
6. Observe the reaction between the hydrochloric acid solution and the pennies. Record your observations in the Observations Table.
7. Set the beaker in a safe place as instructed by your teacher and allow the reaction to continue overnight.

Day 2:

8. Fill a 250-mL beaker about half-full with water.
9. Using tongs, transfer both pennies from the hydrochloric acid solution to the beaker of water. Still using the tongs, move the pennies through the water to rinse them.
10. Remove each penny from the water and hold each under running water to thoroughly rinse it.
11. Look into the center of each penny through one of the notches. Record your observations in the Observations Table.
12. Dry each penny with a paper towel. Write your name on a clean paper towel. Place the pennies next to your name. Allow them to dry completely overnight.

Day 3:

13. Weigh each completely dry penny on a balance. Record the weight of each penny in the Data Tables.

Name: ____________________

Observations Table:

Observations of the Reaction between Hydrochloric Acid and the Pre-1982 Penny	
Observations of the Reaction between Hydrochloric Acid and the Post-1982 Penny	
Observations of the Pre-1982 Penny after being submerged in the Hydrochloric Acid Solution Overnight	
Observations of the Post-1982 Penny after being submerged in the Hydrochloric Acid Solution Overnight	

Data Table — Pre-1982 Penny:

Mass of Notched Penny Before Experiment	
Mass of Dry Penny After Experiment	
Mass of Penny Lost During Experiment	
% Weight of Copper in Penny	
% Weight of Other Metal(s) in Penny	

Data Table — Post-1982 Penny:

Mass of Notched Penny Before Experiment	
Mass of Dry Penny After Experiment	
Mass of Penny Lost During Experiment	
% Weight of Copper in Penny	
% Weight of Other Metal(s) in Penny	

Name: ___________________________

Data Analysis and Questions:

1. Calculate the mass of each penny lost, if any, during the experiment. Record these values in the Data Tables.
2. Did each of the pennies lose approximately the same mass during the reaction, or did they lose different amounts of mass?
3. Based on your observations, did the copper in each penny react with the hydrochloric acid? How do you know?
4. Look at the activity series in Table 1 of the background section. Should copper react with the hydrochloric acid? *Hint: Should copper metal be able to replace hydrogen ions?* Explain your answer.
5. Based on your observations, are the two pennies composed of the same metal(s)? Explain.
6. Looking at the activity series in Table 1 of the background section, propose a metal that could have been used to fill the inside of the post-1982 penny.
7. Write the chemical equation for the reaction between copper metal and hydrochloric acid. If no reaction occurs, write NR on the products side.
8. Write the chemical equation for the reaction between the metal you chose in question 6 and hydrochloric acid.
9. Calculate the % weight of copper in each penny. Record these values in the Data Tables.
10. Calculate the % weight of any other metal(s) in each penny. Record these values in the Data Tables.
11. If the year were rubbed off a penny, how could you determine if the penny was pre-1982 or post-1982 without destroying the penny?
12. Why do you think copper pennies are filled with another metal instead of being made of pure copper?
13. Would it be a good idea to make pennies out of the pure metal you chose in question 6? Why or why not?
14. Describe an experiment that you could carry out in the lab to determine if the hypothesis you made in question 6 was a valid hypothesis.
15. If cost were not a factor, what would be the best metal out of which to make coins? *Hint: Look at the activity series of the metals in Table 1 of the background section.*